Image Processing

Background of the Invention

1. Field of the Invention

The present invention relates to an image processing apparatus and a method of processing image data, in which image data is written to storage devices with redundant parity data.

2. Description of the Related Art

The manipulation of video data within a computer processing environment is well known and over recent years the power of computer systems has increased, large random access memory arrays have become competitively priced and it has become possible to provide modestly priced disk storage by using an array of relatively inexpensive disks with the provision of redundant parity information. Computer systems of this type are usually configured to manipulate pixel data represented as red green blue (RGB) samples within operating systems such as OpenGL. Pixel locations within an image frame are addressed such that data transfers may take place and data manipulations may be performed upon video data in a manner substantially similar to the manipulation of all types of data within a computer system.

A problem with manipulating video data in a computer environment is that often the video data is originally sourced from conventional video equipment where images are supplied sequentially in a video stream in real-time to define a raster. Problems therefore arise in terms of converting between these standards. In particular, video devices are configured to operate in real-time therefore it is preferable for a video transfer to continue in

real-time once it has been initiated thereby optimising the operation of video equipment.

A solution to this problem is described in British patent number 2 312 319B (United States patent application number 08/843,282, assigned to the present Assignee). In the disclosed system, purpose-built hardware provides an interface between a video environment and a computer environment and video data stored on a computer system takes the form of RGB data with parity. In addition, if a disk failure occurs, it is possible for the lost data to be regenerated (a process usually referred to as "healing") automatically as data is read from the disks during normal operation. However, if no disk failures occur, the data remains in protected form and no additional measures are required in order to generate parity information.

The need to construct purpose-built hardware can be eliminated if computer systems are provided with appropriate interface cards to facilitate data transfers. A preferred computer system for operating upon high definition digital video is the ONYX 2 produced by Silicon Graphics Inc. This system is now available with a high definition video card therefore it is possible to transfer high definition digital video signals into the computer system in real-time without additional bespoke circuitry. However, problems occur if, in addition to receiving and storing the incoming data, attempts are also made to perform RAID calculations so as to ensure that protected data is written to storage. It is highly undesirable to disrupt the transfer of video information to the computer system therefore a known approach to this problem is to provide purpose-built hardware RAID configurations for writing the information to disk. This introduces two significant disadvantages. Firstly, additional hardware is required thereby again adding to overall system costs. Secondly, hardware RAID systems are relatively inflexible and need to be

set-up for a particular type of data storage.

An advantageous approach to performing RAID calculations on the host processor is described in United Kingdom patent number 2 312 316B (United States patent application number 08/838,738) assigned to the present Assignee. In particular, the size of a particular input frame is assessed and an optimum number of drives is allocated for the striping of data. This approach also facilitates the storage of data at differing definitions, as is often required in image processing systems. In particular, when operating at high bandwidths, it is preferable to store the data at reduced bandwidth in addition to its full bandwidth version as a sequence of images often referred to as "proxies". The provision of these proxies allows manipulations and effects to be perceived in real-time, whereafter similar processes may be performed on the full bandwidth data effectively off-line. Thus, when performing manipulations upon high definition video, it is known to generate proxies at standard video definition (NTSC) and similarly, when processing standard bandwidth video upon less well equipped machines it is known to generate, store and process proxies of reduced bandwidth in both the horizontal and vertical dimension.

Brief Summary of the Invention

According to an aspect of the present invention, there is provided an image processing apparatus configured to store image data with redundant protection, comprising input means configured to receive an input stream of real-time digital video data; storage means for storing image data; and processing means arranged to perform processing operations on said image data, wherein said input means receives an input stream of real-time digital video data; said processing means performs a first writing operation to write

said video data to said storage means in real-time without parity; said processing means performs a reading operation to read said data from said storage means, perform a data manipulation upon said video data and generate parity information to create protected video data; and said processing means performs a second writing operation to write said protected video data to said storage means.

Brief Description of the Several Views of the Drawings

Figure 1 shows an image processing system;

Figure 2 shows a schematic representation of the system identified in *Figure 1*;

Figure 3 identifies procedures performed by the system shown in *Figure 2*;

Figure 4 shows an alternative hardware configuration;

Figure 5 details capturing and conversion processes as identified in *Figure 4*;

Figure 6 details a process for the calculation of RAID data, identified in *Figure 4*.

Best Mode for Carrying out the Invention

An image processing system is shown in *Figure 1*, in which video images are displayed on a monitor **101** and input commands are generated by an operator via a keyboard **102**, a stylus **103** and a touch tablet 104. These devices are interfaced to an Onyx II computer **105**. Computer **105** is also interfaced to a high definition digital video recorder **106** and a disk array **107**, each configured to convey video material in real-time.

Executable programs may be loaded into the computer **105** from

data carrying media such as CD ROM **108**. Having loaded executable instructions in this way, the computer **105** is then configured to operate in accordance with the procedures detailed herein.

The video system identified in *Figure 1* is shown schematically in *Figure 2*. High definition video images having 1080 horizontal lines each comprising 1920 pixels are displayable in portion **201** of the visual display unit **101**. Visual display unit **101** has a total definition of 1200 lines each comprising 1920 pixels, thereby providing twenty lines at position **202** for the presentation of a graphical user interface to a user of the system. Thus, within region **202**, soft buttons and similar graphical items may be displayed which are then selectable in response to operation of mouse **103**. Alternatively, the system may be configured with a stylus and touch table to provide similar positional information. Furthermore, with the provision of these items, the system may also be responsive to gestural movements of the stylus over the touch tablet.

Onyx computer **104** includes a high definition television (HDTV) graphics card which is in turn interfaced to video tape recorder **105** over a conventional HDTV interface cable **203**. The video tape recorder **105** is capable of recording and playing back video images at high definition in real-time and an example of such a device is the HDV-F600 produced by Sony Corporation of Japan. Operations of VTR **105** are controlled by the computer **104** over a standard serial control interface **204**. Thus, in response to commands generated by computer **104**, the video tape recorder is instructed to perform standard operations, such as the playing back of video tape, in order to provide video signals to computer **104** over interface **203**.

Computer system **104** includes four independent processors and

during the capturing of video data from video tape recorder **105**, data received from interface **203** is distributed to these processors in order to provide a smooth flow of data through the system and thereby enabling the system to continue capturing data in real-time; without being required to pause the operations of video tape recorder **105** and without the risk of corrupting data or possibly missing frames of data, as would happen if real-time operation were to fail. Each processor card in turn controls a respective fibre channel interface thereby providing four fibre channel interfaces **211**, **212**, **213** and **214** communicating with respective disk arrays **221**, **222**, **223** and **224**.

Each disk array, such as array **221**, includes eight independently addressable nine gigabyte disk drives, such as disk drive **227**. Four independent arrays **221** to **224** each having a respective fibre channel are logically considered as a single array having a total of thirty-two disks **227**. Of these, thirty disks are used to store image data, with one of the disks being used to store parity data and the final disk being a spare. The inclusion of a spare disk is important when dealing with a redundant array of inexpensive disks (RAID) because the whole purpose of parity information is to allow lost data to be regenerated when disk failure occurs. Consequently, by including a spare disk, it is possible for this disk to take over from a failed disk and for the regeneration of lost data to be initiated as soon as possible. Thus, in the example shown in *Figure 2*, all of disks **227** are used for storing data, with disk **228** being used for storing the parity information and disk **229** being available as a spare.

When storing high definition television signals, the whole of the disk array is used. However, when storing data of lower definition, it is possible to divide the array into a number of partitions and for a particular data

transfer to occur to a selected partition. In this way, in addition to the storage of high definition television signals, array **106** is also used for storing reduced definition proxies, having a definition substantially similar to standard television broadcast signals.

Proxy images are generated by filtering the high definition data in a process sometimes referred to as "decimation". The lower bandwidth images are then written to a partition of the array **106** from which they are accessible to the computer system **104**. In particular, these proxy images allow manipulations to be performed in real-time, thereby allowing an operator to view an effect prior to a final decision being taken and the operations then being performed in non-real-time upon the high definition material.

It is highly desirable for the video data stored on the disk array **106** to have parity data stored on disk **228**, such that the data is protected and any lost data can be reconstituted from a single disk fail. The parity information is generated upon host processors within system **104** under software control therefore it is not necessary for array **106** to include RAID calculation procedures or hardware, thereby reducing its overall cost while at the same time improving flexibility. However, given the requirements for data throughput during video capture, system **104** is not configured to perform RAID calculations while data received from video tape recorder **105** is being written to the storage array **106**.

An input card **231** within system **104** receives an input stream of real-time digital video data as luminance plus colour difference signals and converts this to RGB samples, possibly with the orientation of the samples being flipped. System **104** performs a first writing operation to write the video data to the storage array **106** in real-time without generating parity. In

this way, the video capturing process is performed smoothly without possible interruption to the video tape recorder **105** and without the possibility of data being corrupted or lost. Thereafter, the processing system **104** performs a reading operation to read the data from the storage array **106** so as to perform further data manipulations upon the video data. In this example, these further manipulations include the generation of reduced bandwidth proxies. In addition, at this stage, parity information is also generated to create protected video data. Thereafter, the processing system **104** performs a second writing operation to write the video data, now in protected form, back to the storage device.

Thus, in order for the data held within the storage array **106** to be in its required format, including the provision of proxies in addition to the high bandwidth signal, it is necessary for the data to be read from the storage array **106**, for manipulations to be performed upon it and then for the data to be written back to the storage device **106**. The present invention takes advantage of this second processing stage and includes the step of generating parity data during this second stage of processing, in preference to the first stage of data capture. In this way, fully protected data is stored within the array **106** while at the same time RAID calculations do not in any way interrupt the data capturing process.

Procedures performed by the system of *Figure 2* are detailed in *Figure 3*. Processes **301**, **302** and **303** are illustrated horizontally and are performed in real-time in response to a real-time video stream received from the video tape recorder **105**. Processes **307** and **308** are illustrated vertically and are performed in machine time after the video material has been captured within the disk storage array **106**.

The digital HDTV stream from video tape recorder **105** is received by

video graphics card **231** which in turn performs a video conversion process **103**. This process involves converting luminance plus colour difference samples into three colour RGB samples. In addition, the ordering of the data may be flipped such that a raster scan originating from the top of an image is converted to an addressed frame originating at the bottom of the image, the latter being consistent with OpenGL protocols.

After the video data has been converted by process **301**, process **302** buffers the data to local random access memory within the computer system **104**. As data is being buffer by process **302** in a revolving manner, process **303** controls the operation of disk storage array **106** and transmits video data over the four fibre channel loops **211** to **214**. Thus, processes **301** to **303** continue in real-time until all of the incoming data has been captured within the disk storage array **106**.

After the incoming video data has been captured within disk storage array **106**, it is then possible for the computer system **104** to perform its non-real-time operation, i.e. in machine-time, in order to ensure that the data has not only been captured and received in real-time but has been processed to ensure that it is has been stored in a preferred way.

At process **307**, RAID calculations are performed upon the data by performing an XOR calculation upon thirty stripes of image data on a pixel-by-pixel basis in order to generate an additional parity bit for each corresponding data bit within the image stripes. This additional data is then written to store **228** such that unprotected data originally stored upon thirty disks has been converted to protected data stored over thirty-one disks.

After a RAID calculation has been performed at step **307**, proxies are generated at step **308** and these proxies of reduced definition are then written back to a partition of the disk storage array **106**.

The procedure of capturing video data and then performing RAID calculations by reading the data and then re-writing the data back to storage has been described with reference to a high definition system using high definition video signals, possibly derived by scanning cinematographic film. The procedure may also be implemented on more modest equipment, such as a Silicon Graphics O_2 machine being used for capturing standard broadcast television signals. Machines of this type do not generally include hardware for video to RGB conversion therefore this also is a further process that may be performed in machine-time after the material has been captured.

A diagram similar to that shown in *Figure 3* is shown in *Figure 4* and relates to a system substantially similar to that shown in *Figure 2* but where the computer system **104** has been replaced by an O_2 system and a video tape recorder **105** is operating at standard broadcast definition. As a consequence of this, the disk array 106 may be reduced from thirty-two disks to typically five disks but again operating as a redundant array.

At process **401** incoming digital NTSC video data is buffered to local storage in a revolving manner. Thus, a plurality of frame buffers are established in local memory such that the operation of disks does not affect the flow of incoming video data in real-time.

At process **402** disks configured over a SCSI array are controlled so as to effect the transfer of data from local storage buffers into a disk storage array **403**. Thus, in this way, the video data has been captured in storage array **103** in real-time thereby allowing a video tape recorder to operate normally, while ensuring that no data is lost or corrupted.

After all of the data has been captured by disk storage array **403**, a process **404** converts the luminance plus colour difference signals into RGB signals. As previously stated, there is no provision of a video input card within

the O_2 computer therefore this process must also be performed off-line. The transfer of data from the disk storage array **403** to the conversion process **404** is illustrated by arrow **407**. After conversion has taken place, the converted data is written back to the storage array **403**, illustrated by arrow **408** and overwrites storage locations occupied by the original input data. In addition to being written to the storage array **403**, the converted RGB data is also conveyed to a RAID calculation process **405** configured to calculate the parity data which is then conveyed back to the disk storage array **403**, as illustrated by path **409**. The converted RGB data from process **404** is also conveyed to a proxy generation process 406 and proxies generated by process **406** are also conveyed back to the disk storage array **403**, as illustrated by path **401**.

Capturing processes and conversion processes identified in *Figure 4* are detailed in *Figure 5*. Incoming video data is received as a stream of pixels with each pixel including eight bits **501** of luminance information followed by eight bits **502** of colour difference information. A first byte of colour difference data C is derived by subtracting the luminance signal Y from a red signal. On the subsequent pixel position, luminance data is followed by colour difference information D this time derived by subtracting luminance signal from a blue input. Thus, the data, referred to as 4:2:2 includes a luminance value for each pixel location but has colour difference signals C and D shared over two pixel positions. Thus, each pixel location includes a total of sixteen bits allocated thereto.

After conversion process **404**, each pixel location includes eight bits **506** representing a red signal, eight bits **507** representing a green signal and eight bits **508** representing a blue signal. Thus, each pixel location requires a total of twenty-four bits.

Data is overwritten within the disk storage array **403**. A disk storage array **403** is illustrated in *Figure 5* as **403Y** when captured **422** data and as **403R** when storing converted RGB data. Another constraint of the O_2 system is that it is not possible to transfer data in real-time at RGB bandwidth, but it possible to convey video data in real-time for **422** bandwidth. Consequently, during the capturing process the data is written in packed 2:4:4 form as illustrated at **512**. **403Y** represents the total volume of the storage space and after a capturing operation shaded portion **513**, in this example, has received the captured video.

During conversion process **404**, two pixels containing four samples are expanded to two equivalent pixels containing three samples, as illustrated by samples **506**, **507** and **508**. This results in the total space contained within disk **403R** being expanded to shaded region **514**. In this way, it is possible to capture the data in real-time without requiring full RGB bandwidth to the disk during the writing operation. Conversion process **404** to RGB also results in an expansion of the total amount of disk space addressed for the storage of the data.

Thus, after conversion process **404**, sufficient space is available for eight bytes of red data, eight bytes of green data and eight bytes data of blue to be held within the same storage locations. Thus, for each two bytes **501**, **502** of real-time video data captured by the system, three bytes **506**, **507** and **508** are stored after conversion to RGB. In the high definition system shown in *Figure 3*, this conversion is performed by the input card and immediately written to disk in RGB form. In the low definition system illustrated with respect to *Figure 4*, it is not possible to perform this conversion as the data is received therefore the process is performed as part of the data manipulation carried out between reading the data and then

writing it for a second time. Consequently, given that the original data is overwritten in the low definition system, it is necessary to ensure that space is provided for this additional data during the capturing process, as illustrated in *Figure 5*.

Process **405** for the calculation of RAID data is illustrated in *Figure 6*. In this low definition system, an image frame **601** is divided into five stripes **602**, **603**, **604**, **605** and **606**. In the high definition system illustrated in *Figure 3*, a similar striping process is performed with the image frame being divided into thirty stripes. After being buffered at process **401**, stripes are effectively read in parallel such that each stripe may be considered as reading the image, with a predetermined off-set defining the stripe position.

Transfer to disk occurs over a serial SCSI interface, with five of the SCSI channels being employed to effect transfer to a respective disks **612**, **613**, **614**, **615**, **616** for each of the video stripes. In addition, outputs from the video stripes are supplied to an XOR process **618**. Within each stripe, pixels have similar addresses but with increments of stripe off-sets. Thus, a particular pixel in stripe zero has a corresponding pixel in stripe one, which has a corresponding pixel in stripe two, a corresponding pixel in stripe three and a corresponding pixel in stripe four. Similarly, the pixels made up of twenty-four bits, as illustrated in *Figure 5*, have corresponding bits derived from each stripe. These corresponding bits for each stripe are XORd in order to provide data which is supplied to a parity disk **619**. If any of disks **612** to **616** or parity disk **619** fails, it is replaced by spare disk **620**. Outputs from all of the remaining disks are XORd in order to regenerate the lost data which is then written to the spare disk **620**, which may then logically take its place within the disk array.

The redundant parity data written to disk **619** is calculated after the

data has been read from storage **303** and forms part of a manipulation being performed on the data before the protected data is then written back to storage under a second writing step. In the high definition system, the manipulation includes a generation of proxy data and in the lower definition system the manipulation also includes a conversion to RGB. In this way, protected data is generated without undermining the real-time capture process.

Many techniques are known for the generation of proxies which, in its simplest form, merely involves the selection of some pixels in preference to other pixels on a regular basis with a minimal degree of filtering. In more sophisticated systems, two dimensional filtering is produced, which, for example, may generate a single pixel by averaging four or more adjacent pixels. In the majority of applications, the sophistication of process **406** or process **308** will depend upon the sophistication of processes requiring this proxy information. It should be understood that the manipulation of proxy information merely provides an operator with an indication of a particular effect and that the final effect is performed on the full definition data.